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Date of Filing : 22 NOV 2002

Application Number : PCT/SG02/00302 [withdrawn]

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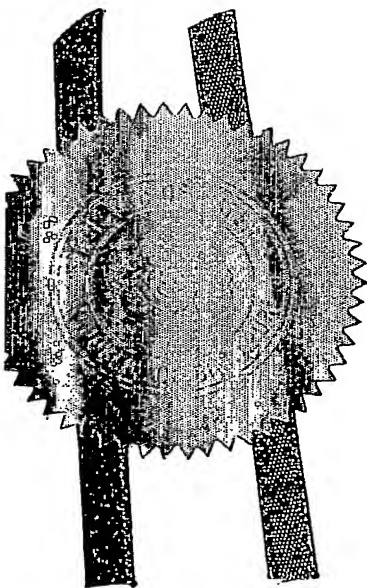
Title of Invention : SOL-GEL BASED HEATING ELEMENT

1B/03/4865


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PNL021213WOP

PCT REQUEST

Original (for SUBMISSION) - printed on 22.11.2002 01:06:00 PM

0	For receiving Office use only	
0-1	International Application No.	PCT/SG 0 2 / 0 0 3 0 2
0-2	International Filing Date	2 2 NOV 2002 (22-11-02)
0-3	Name of receiving Office and "PCT International Application"	REGISTRY OF PATENTS (SINGAPORE) PCT INTERNATIONAL APPLICATION
0-4	Form - PCT/RO/101 PCT Request	
0-4-1	Prepared using	PCT-EASY Version 2.92 (updated 01.10.2002)
0-5	Petition	
	The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	Receiving Office (specified by the applicant)	Intellectual Property Office of Singapore (RO/SG)
0-7	Applicant's or agent's file reference	PNL021213WOP
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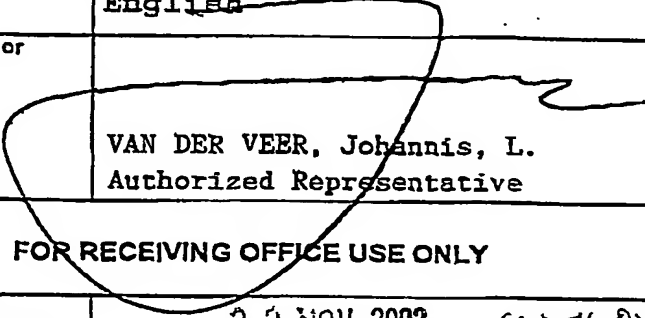
PNL021213WOP

V	Designation of States		
V-1	Regional Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	EP: AT BE CH&LI CY DE DK ES FI FR GB GR IE IT LU MC NL PT SE TR and any other State which is a Contracting State of the European Patent Convention and of the PCT (except BG CZ EE SK)	
V-2	National Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	SG	
V-5	Precautionary Designation Statement In addition to the designations made under Items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.		
V-8	Exclusion(s) from precautionary designations	NONE	
VI	Priority claim	NONE	
VII-1	International Searching Authority Chosen	European Patent Office (EPO) (ISA/EP)	
VIII	Declarations	Number of declarations	
VIII-1	Declaration as to the identity of the inventor	-	
VIII-2	Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent	-	
VIII-3	Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application	-	
VIII-4	Declaration of inventorship (only for the purposes of the designation of the United States of America)	-	
VIII-5	Declaration as to non-prejudicial disclosures or exceptions to lack of novelty	-	
IX	Check list	number of sheets	electronic file(s) attached
IX-1	Request (including declaration sheets)	3	
IX-2	Description	10	-
IX-3	Claims	2	-
IX-4	Abstract	1	-
IX-5	Drawings	1	EZABST00.TXT
IX-7	TOTAL	17	-

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	Accompanying Items	paper document(s) attached	electronic file(s) attached
IX-8	Fee calculation sheet	✓	-
IX-11	Copy of general power of attorney	✓	-
IX-17	PCT-EASY diskette	-	Diskette
IX-19	Figure of the drawings which should accompany the abstract	1	
IX-20	Language of filing of the international application	English	
X	Signature of applicant, agent or common representative		
X-1	Name (LAST, First)	VAN DER VEER, Johannis, L.	
X-2	Capacity	Authorized Representative	

FOR RECEIVING OFFICE USE ONLY

10-1	Date of actual receipt of the purported international application	22 NOV 2002 (22-11-02)
10-2	Drawings:	
10-2-1	Received	
10-2-2	Not received	
10-3	Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application	
10-4	Date of timely receipt of the required corrections under PCT Article 11(2)	
10-5	International Searching Authority	ISA/EP
10-6	Transmittal of search copy delayed until search fee is paid	

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11-1	Date of receipt of the record copy by the International Bureau	
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Sol-gel based heating element

The present invention relates to a heating element comprising an electrically insulating layer and an electrically conductive layer, as well as to an electrical domestic appliance comprising such heating element.

5 In general a (flat) heater system comprises two functional layers applied on a substrate, namely an electric insulating layer and an electrical conductive layer. The electrically conductive layer in the above mentioned heating element generally comprises a layer with a high Ohmic resistance, the resistive layer, as well as a layer with a lower Ohmic resistance, which acts as a contacting layer. Heat is generated by flowing an electrical current through the resistive layer. The function of the insulating layer is to isolate the heat
10 generating resistive element from the substrate, which may be directly accessible from the outside.

The invention specifically relates to a flat heating element that is suitable for high power densities, for instance for application in laundry irons and other domestic appliances.

15 Thick film processing for making flat heating elements involves curing steps, which should be limited to a temperature compatible with the substrate. For aluminum substrates the maximum curing temperature is rather low and therefore flat-heating materials based on glasses are generally not suitable. Low melting point glasses often contain lead or other undesired metals, which are to be avoided, as well as a significantly lower thermal
20 expansion coefficient than aluminum and aluminum alloys. Polymer based materials, such as epoxies, or silicone resins do not have sufficient temperature stability to be used in a heating element. An important factor in this respect is the temperature drop over the insulating layer, which can be quite substantial and which depends on the thickness of the electrically insulating layer. This makes polymer based materials especially unsuitable for high power
25 densities, where the track temperatures can easily be about 100°C higher than the heating face of the substrate for only a 50 µm thick insulating layer.

WO 02/072495 discloses a composition for application to a substrate to form an electrically conductive coating thereon. The composition includes a sol-gel solution filled with conductive powder. The sol-gel solution comprises a non-hybrid sol-gel, such as

alumina sol-gel or silica sol-gel. WO02/072495 also discloses a heating device comprising the above composition, in which a thick insulating layer up to about 500 μm is applied. In order to protect the conductive layer against oxidation an oxidation barrier layer has to be applied over said conductive heating layer. This treatment makes the device less sensitive to corrosion but introduces extra processing steps.

The present invention aims to provide for a heating element according to the preamble, which does not have the above disadvantages, and provides for a relative high power density. Moreover, the present invention aims to provide for a heating element that can advantageously be applied on aluminum and aluminum alloy substrates.

To this end the present invention provides for a heating element comprising an electrically insulating layer and an electrically conductive layer, where at least the electrically conductive layer is based on a hybrid sol gel precursor comprising an organosilane compound.

By applying such hybrid sol gel precursor, a heating element can be provided with higher power densities and a reduced risk of oxidation of the conductive layer. The hybrid sol gel precursors as disclosed in the present invention differ from the non-hybrid precursors as disclosed in WO 02/072495. The hybrid sol gel precursors as used herein can be characterized as compounds comprising silicium, which is bond to at least one non-hydrolysable organic group, and 2 or 3 hydrolysable alkoxy groups. The application of the hybrid sol gel precursors according to the present invention results in a heating element with very advantageous properties.

According to the present invention at least the electrically conductive layer is based on a hybrid sol gel precursor. Advantageously, also the electrically insulating layer is based on a hybrid sol gel precursor. Such electrically insulating layer is also disclosed in WO 02/085072.

The sol-gel material according to the present invention can be processed at temperatures below 450°, which makes them suitable to be applied directly to aluminum substrates. Although the sol-gel material is especially suitable for application on aluminum or aluminum alloy substrates, other substrates that are conventionally used for heating elements and that are compatible with the final utility may also be used. Said substrates may include, for example, stainless steel, enameled steel or copper. The substrate may be in the form of a flat plate, a tube or any other configuration that is compatible with the final utility.

In particular, the hybrid sol-gel precursor comprises an organosilane compound from the group of alkyl-alkoxysilanes.

Preferably, the hybrid sol-gel precursor comprises methyl-trimethoxysilane and/or methyl-triethoxysilane.

In order to obtain a heating element with a relative high power density, a reduced risk of oxidation of the resistive layer, and optimized thermal expansion coefficient values for aluminum and aluminum alloys the hybrid sol gel precursors according to the present invention should be used. Hybrid sol gel precursors such as methyl-trimethoxysilane (MTMS) and methyl-triethoxysilane (MTES) are known to have excellent temperature stability up to at least 450°C. Moreover MTMS has been shown to prevent silver oxidation and subsequent migration effectively. The carbon content of these materials is still low, so carbonized conductive tracks across the insulating layer will not form after failure, making a safe flat heating element. The maximum layer thickness of coatings made from hybrid precursors is relatively high, compared to the maximum layer thickness of coatings made from non-hybrid sol gel materials. Therefore the layers can be deposited in one or at most two steps without intermediate curing.

Advantageously, the electrically insulating layer comprises non-conductive particles.

A fraction of said non-conductive particles preferably have a flake-like shape and a longest dimension of 2-500 micrometer, preferably from 2-150 micrometer, and more preferably from 5-60 micrometer. These flake-like non-conductive particles are based on oxidic materials like for example mica or clay, and/or surface modified mica or clay particles with a coating of titaniumdioxide, aluminum oxide and/or silicon dioxide. The flake-like material content in the insulating layer should be less than 20 volume %, preferably less than 15 vol%, and more preferably 4-10 volume %.

An advantage of such anisotropic particles is that their presence prevents the formation of cracks in the electrically insulating layer after frequent heating up and cooling down of the heating element.

In the preferred embodiment, the other non-conductive particles are present in a colloidal form. Examples thereof are oxidic materials like aluminum oxide and silicon dioxide. Preferably, the aluminum oxide content in the insulating layer should be less than 40 volume %, preferably less than 20 volume %, more preferably 10-15 volume %. As for the silicon dioxide content in the insulating layer, it should advantageously be less than 50 volume %, preferably less than 35 volume %, more preferably 15-25 volume %.

If an insulating layer based on MTMS or MTES filled with particles, including anisotropic particles is made, a layer thickness of just 50 μm can withstand 5000V. This

relatively small layer thickness allows the temperature of the resistive track to be fairly low. For a specific high power density application of 50 W/cm^2 and that requires a heating face temperature of 250°C , a conductive track temperature of only 320°C is required. On the contrary, for an insulating layer thickness of $300 \mu\text{m}$, an excess temperature for the heat generating conductive layer of about 600°C would be required. For this reason said thin insulating layers are advantageously used. The layers can be applied by any wet chemical application method, preferably spray coating or screen-printing followed by a curing step.

The heating elements according to the present invention are very suitable for heating elements in laundry irons, especially for the controlled formation of steam, for which high power densities are required. However, the heating elements are also very suitable for other domestic applications, like hair dryers, hair stylers, steamers and steam cleaners, garment cleaners, heated ironing boards, facial steamers, kettles, pressurized boilers for system irons and cleaners, coffee makers, deep fat fryers, rice cookers, sterilizers, hot plates, hot-pots, grills, space heaters, waffle irons, toasters, ovens or water flow heaters.

In the following the heating element according to the present invention, as well as the processing steps for providing said heating element, are described in more detail by way of example.

The materials and processing are provided for making a thin heating element onto a metal substrate such as aluminum. For the insulating layer a hybrid sol gel solution, made preferably of MTMS or MTES, water and filled with oxidic particles such as, silica, alumina and titania is prepared by hydrolysis using a suitable acid. It was found to be specifically beneficial to include strongly anisotropic particles, such as mica or commercially available interference pigments in the formulation to maintain high dielectric breakdown strengths during use. This coating liquid can be applied onto an aluminum substrate, preferably an anodized aluminum substrate, to ensure good adhesion of the sol gel layer. Normally two layers are sprayed, with a short intermediate drying step, but without the need of an intermediate curing step. This leads to a final coating layer thickness of about $50 \mu\text{m}$. Advantageously, the insulation layer has a thickness of $25\text{-}100 \mu\text{m}$, preferably $35\text{-}80 \mu\text{m}$.

Curing takes place at a temperature of around 415°C , depending on the substrate and application requirements.

On top of the insulating layer a conductive layer or track is applied. Advantageously, the electrically conductive layer comprises conductive and/or semi-conductive particles, as well as an amount of insulating particles of $0\text{-}20 \%$ by volume. The insulating particles may be added to modify the resistance of the layer or track.

Advantageously, the electrically conductive layer does not exceed 30 μm in thickness and preferably does not exceed 15 μm in thickness.

The preferred technique for applying the conductive tracks is screen-printing. For the conductive track commercially available metal powders can be used. It is preferred to use silver or silver alloy particles. Mixing of the silver particles with palladium particles or the use of silver-palladium alloys both lead to a change in resistivity while the positive temperature coefficient is reduced in its value. Graphite can also advantageously be used to make conductive tracks. Other metals and semiconductors can be used in making conductive layers for the application provided they have sufficiently high temperature stability in the hybrid sol gel matrix. The use of MTMS or MTES precursors reduces the rate of oxidation of silver and graphite particles at the high temperatures in application. In that respect it can be noted that graphite in an MTES derived matrix has shown a long term stability (over 600 hours) at 320 °C.

The conductivity achieved depends on the volume fraction of conductive particles in the conductive layer, and can be further influenced by the addition of non-conductive particles. The addition of non-conductive particles can either increase or decrease the layer conductivity.

To make the formulations screen printable, a cellulose derivative is added to the particle containing, hydrolyzed MTMS or MTES solution. As a cellulose material preferably hydroxy-propyl-methyl-cellulose is used. Finally a solvent with a high boiling point is added to prevent drying of the ink and subsequent clogging of the screen. Butoxyethanol was found to be a suitable choice, but other polar solvents, preferably alcohols, are also appropriate.

A protective layer to prevent corrosion is not needed onto this stack of layers. However, for the sake of mechanical integrity during handling and production it can be beneficial to deposit such a layer. Using for instance a silica filled hybrid sol gel solution, based on for example MTMS, a screen printable formulation can be easily made. The applied topcoat layer can be co-cured with the conductive layers.

The such prepared heating elements were subjected to over 600 temperature cycles, in which the element was maintained for 1 hour at 320 °C, and subsequently switched off during 30 minutes. The high temperature was obtained by passing electrical current through the conductive layers, by which power densities of 10 to at least 120 W/cm^2 could be achieved.

The invention will be further elucidated with reference to the following embodiment, the following manufacturing examples and the enclosed drawing, in which:

Fig. 1 shows a sectional view of an embodiment of the heating element according to the present invention.

It is noted that the various elements are purely schematic and are not drawn to scale.

The heating element 1 as shown in figure 1 is built up of a substrate 2, an insulating layer 3, and an electrically conductive layer or resistive layer 4.

In the embodiment shown, the substrate 2 comprises aluminum or an aluminum alloy which is used for a sole plate of an iron. Said substrate 2 is covered with a layer 3 of an electrically insulating material. In the example, the electrically insulating layer 3 is based on a hybrid sol-gel precursor and has a thickness of 50 μm . The resistive layer 4 comprises a track of a conductive coating – not specifically shown in the figure – with high Ohmic resistance, which is, in the present example, screen printed on the insulating layer 3.

Example 1

A lacquer was prepared from 32.82 g of MethylTrimethoxySilane (MTMS) 12.62 g aluminiumoxide CR6 (Baikalox), 16.41 g of ethanol, 0.31 g maleic acid, and 34.95 g of a colloidal silica suspension Bindzil 40NH3/80 (EKA Chemicals). The water from the silica suspension was used to hydrolyze the alkoxysilanes. To the lacquer 2.89 g of a commercially available flake-like, mica based pigment was added to reduce the sensitivity to crack formation.

After completion of the hydrolysis reaction, the lacquer was spray coated onto a 3mm thick, anodized aluminum substrate. The anodic layer thickness was less than 4 micron and served as a primer layer for the sol-gel insulating layer.

The layers were subsequently cured at 415 °C to obtain a dry film thickness of 50 μm . The dielectric strength of this layer is higher than 10^8 volt/m. This coating was able to withstand more than 1000 cycles of heating-up to 320 °C and cooling-down to room temperature. After 1000 cycles still no crack formation was observed and no deterioration of the dielectric breakdown strength was measured.

Comparative example 1.

A coating similar to that in example 1 was prepared, except for the addition of the flake-like pigment to the lacquer. The dielectric strength of this layer is higher than 10^8 V/m. This coating was able to withstand only 300 cycles of heating-up to 320°C and cooling-down to room temperature. After 300 cycles severe crack formation was observed, leading to breakdown voltages of less than 600 V, which is too low for application in domestic appliances.

Example 2

A heating element was prepared starting from an aluminum substrate provided with an insulating layer as described in example 1. Onto this layer a conductive track was printed using a paste prepared according to the recipe given below.

A hydrolysis mixture was prepared from 84.8 grams of methyltriethoxysilane, 51.2 grams of water, and 0.24 grams of glacial acetic acid. The mixture was stirred continuously for 5 hours. To 36 grams of this hydrolysis mixture 3.85 grams of disperbyk 190 was added followed by 77.8 grams of a commercially available silver powder with a particle size below $20\text{ }\mu\text{m}$. Subsequently 36 grams of n-propanol was added to the mixture which was subsequently ball milled overnight on a roller conveyor.

After removal of the milling balls, 35 grams of a 6% hydroxypropyl-methylcellulose solution in water was added to 120 grams of the mixture. After mixing a homogeneous paste was obtained which was screen printed on said insulating sol gel layer. The layers were dried at 80°C and subsequently cured at 415°C . A single layer had a thickness of about $5\text{ }\mu\text{m}$ and a sheet resistance of $0.046\text{ }\Omega$ per square. The quality was such that the sample-to-sample variation of the sheet resistance was less than 5%. The heating element was powered up actively by application of an electrical current through said conductive layer to obtain a temperature of 320°C . The sheet resistance was found to decrease to a plateau value of about 20% below the initial resistance value after prolonged exposure to said temperature. This plateau value was reached within 60 hours of exposure to said temperature.

Example 3

A similar heating element as described in example 4 was prepared, except for the fact that the conductive layer printing was repeated after drying of the first printed conductive layer. After drying and curing of the conductive layer stack a layer thickness of $10\text{ }\mu\text{m}$ was measured. The double pass printed conductive layers had a sheet resistance of $0.024\text{ }\Omega$ per square. The quality was such that the sample-to-sample variation of the sheet resistance was less than 5%. The heating element was powered up actively by application of

an electrical current through said conductive layer to obtain a temperature of 320 °C. The sheet resistance was found to decrease to a plateau value of about 20% below the initial resistance value after prolonged exposure to said temperature. This plateau value was reached within 60 hours of exposure to said temperature.

5 Example 4

A heating element was prepared starting from an aluminum substrate provided with an insulating layer as described in example 1. Onto this layer conductive and contacting tracks were printed using paste materials prepared according to the recipes given below.

10 A hydrolysis mixture was prepared from 56.0 grams of methyltriethoxysilane, 33.8 grams of water, and 0.16 grams of glacial acetic acid. The mixture was stirred continuously for 5 hours after which 7.95 grams of Disperbyk 190 was added followed by 31.74 grams of graphite powder with a particle size of around 10 µm.

15 The mixture was ball-milled overnight on a roller conveyor. After removal of the milling balls 60 grams of a 6% hydroxypropyl-methylcellulose solution in water was added to 100 grams of the mixture, followed by 50 grams of n-propanol. After mixing a homogeneous paste was obtained which was screen printed on said insulating sol gel layer to form a conductive layer.

20 After drying of the conductive layer, a contacting layer based on the recipe disclosed in example 2 was screen printed on said substrate. The contacting layer partially overlapped with the conductive layer to form a low Ohmic contact.

25 The screen-printed layers were dried at 80°C and subsequently cured at 415 °C. For single pass printing a layer thickness of about 5 µm was obtained. The sheet resistance of the conductive layer was 57 Ω per square. The quality was such that the sample-to-sample variation of the sheet resistance was less than 10%. The heating element was powered up actively by application of an electrical current through said conductive layers to obtain a temperature of 320 °C. Prolonged exposure to said temperatures did not show any significant change in sheet resistance.

Example 5

30 A similar heating element as described in example 4 was prepared, except for the fact that the contacting layer was applied before the conductive layer. The sheet resistance of the conductive layer was 57 Ω per square. The quality was such that the sample-to-sample variation of the sheet resistance was less than 10%. The heating element was powered up actively by application of an electrical current through said conductive

layers to obtain a temperature of 320 °C. Prolonged exposure to said temperatures did not show any significant change in sheet resistance.

Example 6

A similar heating element as described in example 4 was prepared, except for the fact that the conductive layer printing was repeated after drying of the first printed conductive layer. After drying and curing of the conductive layer stack a layer thickness of 10 μm was measured. The double pass printed conductive layers had a sheet resistance of 26 Ω per square. The quality was such that the sample-to-sample variation of the sheet resistance was less than 10%. The heating element was powered up actively by application of an electrical current through said conductive layers to obtain a temperature of 320 °C. Prolonged exposure to said temperatures did not show any significant change in sheet resistance.

Example 7

A heating element was prepared starting from an aluminum substrate provided with an insulating layer as described in example 1. Onto this layer a conductive track was printed using a paste prepared according to the recipe given below.

To 16 grams of the hydrolysis mixture as described in example 4, 1.7 grams of disperbyk 190 was added followed by 35 grams of a commercially available silver powder (particle diameter smaller than 20 μm), 1.35 grams of Al_2O_3 (Baikalox CR6) and 16 grams of 1-propanol. This mixture was ball milled overnight. After removal of the milling balls, 13 grams of a 6% HPMC solution in water was added and the resulting paste was screen-printed onto said insulating sol-gel layer. After drying at 80°C and curing at 415°C, a layer thickness of 6 μm resulted with a sheet resistance of 0.07 Ω per square.

Example 8

A flat-heating element was prepared according the description in example 2 with the difference that after printing of the conductive layer, a hybrid topcoat layer was printed.

The topcoat was prepared from a hydrolysis mixture based on 37.35 grams of methyltriethoxysilane, 22.55 grams of water, and 0.10 grams of glacial acetic acid. The mixture was stirred continuously for 5 hours after which 9.6 grams of Disperbyk 190 was added followed by 41.0 grams of titaniumdioxide powder with a particle size of around 250 nm. The mixture was ball-milled overnight on a roller conveyor. After removal of the milling balls 36 grams of a 6% hydroxypropyl-methylcellulose solution in water was added to 60 grams of the suspension, followed by 30 grams of n-propanol. After mixing a homogeneous

paste was obtained which was screen-printed over the complete flat-heating element except for two contacting pads. The topcoat screen printing step was carried out before said curing treatment of the conductive layer. After drying at 80 °C the complete coating stack was cured at a temperature of 350 °C.

5 The measured resistance of the conductive track was 0.047 Ω per square.

Example 9

A flat-heating element was prepared according to the description in example 2 with the difference that a defect in the conductive layer was induced by means of the placement of a human hair on the substrate before the application of the conductive layer.

10 After the conductive layer was printed, the human hair was removed leaving behind a defect in the conductive layer.

The heating element was subsequently dried at 80 °C followed by a curing step at 350 °C.

15 Next the heating element was powered up by application of a current of 9 A induced by an alternating voltage difference of 220 V. Sparking of the element was observed at the position of the hair defect in the conductive layer, leading to failure of the element. The quality of the insulating layer was tested by application of a voltage difference of 1250 V between the conductive track and the aluminum substrate for a period of 60 seconds. The leakage current measured was measured to be less than 1 mA, fulfilling the safety
20 requirements.

CLAIMS:

1. A heating element comprising an electrically insulating layer and an electrically conductive layer, where at least the electrically conductive layer is based on a hybrid sol gel precursor, comprising an organosilane compound.
- 5 2. A heating element according to claim 1, characterized in that the hybrid sol-gel precursor comprises a compound from the group of alkyl-alkoxysilanes.
3. A heating element according to claim 1 or 2, characterized in that the hybrid sol-gel precursor comprises methyl-trimethoxysilane and/or methyl-triethoxysilane.
- 10 4. A heating element according to claim 1, characterized in that the electrically insulating layer comprises non-conductive particles.
5. A heating element according to claim 4, characterized in that the electrically
15 insulating layer comprises anisotropic, non-conductive particles.
6. A heating element according to claim 1, characterized in that the electrically conductive layer comprises conductive and/or semi-conductive particles, as well as an amount of insulating particles in a volume of 0-20 %.
- 20 7. A heating element according to claim 6, characterized in that the electrically conductive layer comprises metal particles.
8. A heating element according to claim 7, characterized in that the electrically
25 conductive layer comprises silver or silver alloy particles.
9. A heating element according to claim 6, characterized in that the electrically conductive layer comprises graphite or carbon-black particles.

10. A heating element according to claim 1, characterized in that the electrically conductive layer does not exceed 30 μm in thickness and preferably does not exceed 15 μm in thickness.
- 5 11. A heating element according to claim 1 comprising an insulating layer having a thickness of 25-100 μm , preferably 35-80 μm .
12. A heating element according to any of claims 1-11, applied on an aluminum or aluminum alloy substrate.
- 10 13. An electrical domestic appliance comprising at least a heating element in accordance with any one of claims 1-11.
- 15 14. An electrical domestic appliance according to claim 13, characterized in that the electrical domestic appliance comprises a (steam) iron, hair dryers, hair stylers, steamers and steam cleaners, garment cleaners, heated ironing boards, facial steamers, kettles, pressurized boilers for system irons and cleaners, coffee makers, deep fat fryers, rice cookers, sterilizers, hot plates, hot-pots, grills, space heaters, waffle irons, toasters, ovens or water flow heaters.

ABSTRACT:

Disclosed is a heating element comprising an electrically insulating layer and an electrically conductive layer. At least the electrically conductive layer is based on a hybrid sol gel precursor, comprising an organosilane compound.

5 Also disclosed is an electrical domestic appliance comprising the above heating element. Examples of such domestic appliance include (steam) irons, hair dryers, hair stylers, steamers and steam cleaners, garment cleaners, heated ironing boards, facial steamers, kettles, pressurized boilers for system irons and cleaners, coffee makers, deep fat fryers, rice cookers, sterilizers, hot plates, hot-pots, grills, space heaters, waffle irons, toasters, ovens or water flow heaters.

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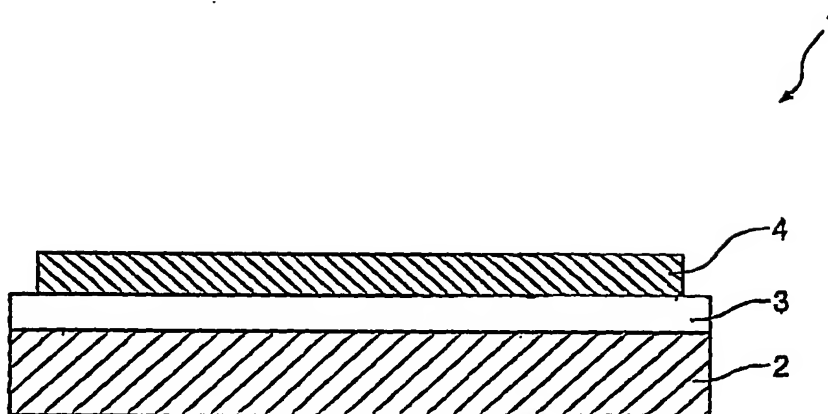


FIG. 1